NAME:____ CLASS:_______________

LAB12: Refraction of Light

INTRODUCTION

A light ray normally travels in a straight line, as long as the medium it is traveling through has a constant density. However when a light ray encounters another medium, for example when it travels from air into glass, the ray can bend. This is called refraction.

When light enters a denser medium, it bends towards the normal (a line perpendicular to the surface). The amount that the light bends depends on the ratio of the indexes of refraction of the two materials, basically the ratio of their optical densities.

TERMS:

- REFRACTION: The bending of light when it passes from one medium to another.
- NORMAL: a line perpendicular (at 90 degrees) to a surface
- ANGLE OF INCIDENCE [θ_i]: The angle between an incoming light ray and the normal line.
- ANGLE OF REFRACTION [θ_r]: The angle between a refracted light ray and the normal line.
- INDEX OF REFRACTION [n]: an experimental value that is based on the ratio of the speed of light in a vacuum to the speed of light in some other medium, $n = c / v$, can also be used to determine the amount of bending of light when entering that medium.

PURPOSE

The purpose of this lab is to experimentally illustrate the Law of Refraction (Snell's Law) by determining the index of refraction of unknown transparent plates. You will construct ray diagrams to analyze the path of light as it travels through two pieces of unknown plates. You will measure the angle of incidence and refraction, and determine the index of refraction for each material using Snell's Law, and then compare them to the accepted values.

MATERIALS

- ☐ Rectangular and Triangular transparent plates
- ☐ Ruler
- ☐ Protractor
- ☐ Paper
- ☐ Pencil
- ☐ Laser or Laser Ray Box
- ☐ Glass rod (if using a regular laser)

PROCEDURE

RECTANGULAR PLATE

1. Place the Rectangular Plate in the center of a sheet of plain white paper. Trace the outline of it with a pencil.
2. Use your ruler to draw a heavy LINE A as shown at an *angle of incidence* [θ_i] around 45 degrees as shown in Figure A.
3. Remove the plate and construct a normal line (N1) at the top left of the outline as shown in Figure A on the following page. Make sure it is perpendicular to the surface and goes through the point where the heavy line intersects the plate surface.
4. Measure the angle and record it on your diagram.

NAME: _______ CLASS: _________________

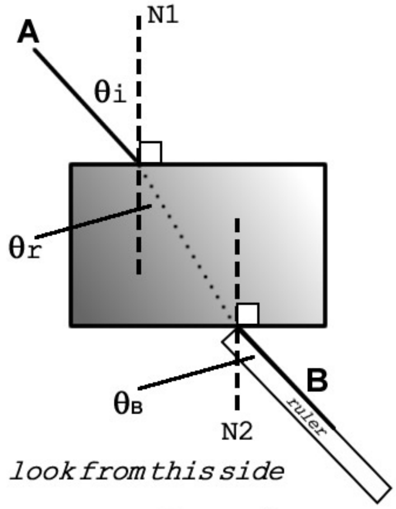

Figure A

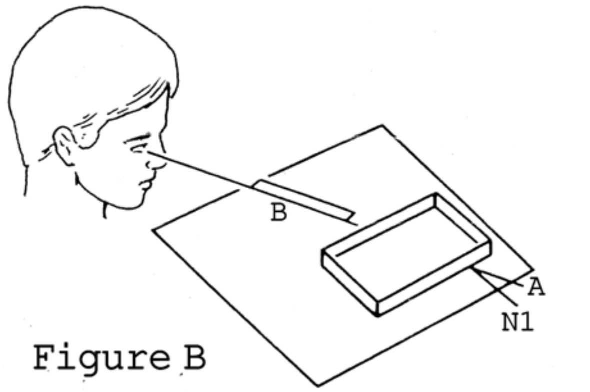

Figure B

5. Replace the transparent plate over the outline on the paper. With your eyes level with the desk (yes you will have to squat down) look along the side of the plate opposite LINE A until you can see the heavy line you drew through the side of plate as shown in Figure B. Use your ruler and line it up so that it looks like it is a continuation of the line from the other side. Draw in LINE B along your ruler as shown in Figure A.
6. Remove the transparent plate and draw in another Normal Line (N2) that is perpendicular to the other side of the transparent plate and meets LINE B at the surface as shown in Figure A.
7. Connect the ends of LINE A and LINE B through the two normal lines as shown by the dotted line in Figure A.
8. Using your protractor, measure the *angle of refraction* $[\theta_r]$ as well as the angle $[\theta_B]$ as shown in Figure A, and record them on your diagram.
9. **QUICK CHECK**: if done right, θ_B should be very close to θ_i. If it is not try lining up the heavy line again.
10. Repeat the process 3 more times for different angles of incidence, and record your results in a data table. If it gets too messy, you may want to use a second piece of paper.

MEASURING THE INDEX OF REFRACTION WITH THE LASER

11. Using the same transparent block and a new piece of paper, setup the laser as shown. You should place the glass rod parallel to the incident surface and in between the laser and the surface. Again trace the transparent block.
12. Activate the laser and position it so that you can see the beam going in and out of the transparent plate. You may have to move the glass rod and the laser farther away to get a good beam coming out of the transparent block. Hold it steady and have your partner mark two dots along the incoming path and two dots along the out going path.
13. Turn off the laser, remove the transparent block and connect the dots creating the path of light in, through, and out of the block.
14. Using your protractor, measure the *angle of refraction* $[\theta r]$ as well as the angle $[\theta_B]$ as shown in Figure A, and record them on your diagram and in your data table.
15. Repeat the process 3 more times for different angles of incidence, and record your results in a data table.

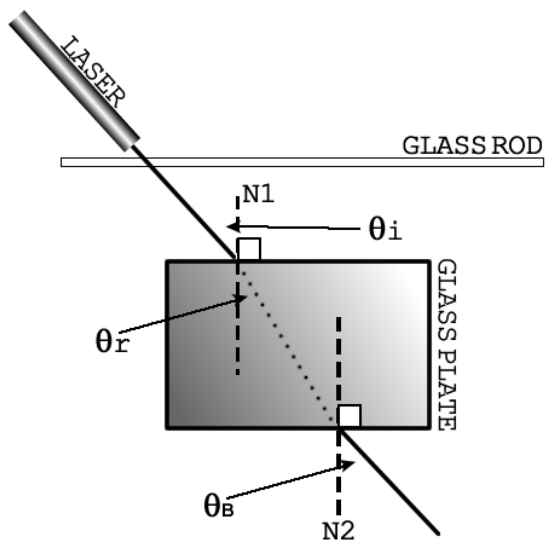

Figure C

NAME:____ CLASS:________________

TRIANGULAR PLATE

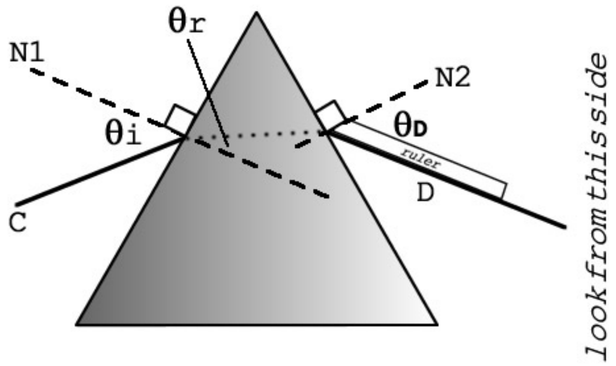

Figure C

16. Place the Triangular Plate in the middle of a new piece of paper. Trace the outline of it with a pencil.
17. Remove the plate and construct a normal line at the top left of the outline as shown in Figure C.
18. Use your ruler to draw a heavy LINE C as shown at an *angle of incidence* [θi] around 45 degrees as shown in Figure C. Measure the angle and record it on your diagram.
19. Replace the transparent triangle plate over the outline on the paper. With your eyes level with the look along the side of the plate opposite LINE C until you can see the heavy line you drew through the glass, just as you did with the rectangular plate. Use your ruler and line it up so that it looks like it is a continuation of the line from the other side. Draw in LINE D along your ruler as shown in Figure C.
20. Remove the transparent plate and draw in another Normal Line (N2) that is perpendicular to the other side of the glass plate and meets LINE C at the surface as shown in Figure D.
21. Connect the ends of LINE C and LINE D through the two normal lines as shown by the dotted line in Figure C.
22. Using your protractor, measure the *angle of refraction* [θ_r] as well as the angle [θ_D] as shown in Figure C, and record them on your diagram.
23. Repeat the process using the laser instead of the pencil mark as before.

NAME:____ CLASS:_______________

ANALYSIS

You can now use Snell's Law to determine the indexes of refraction of the rectangular glass and the triangular glass. Snell's Law states that the index of refraction of one medium multiplied by the sine of the angle a light ray makes with the normal in it is equal to the index of refraction of a second medium multiplied by the sine of the angle the light ray makes with the normal in the medium, when the ray travels from one medium to the other. Or in mathematical terms,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

In our case, $\mathbf{n_1}$ is $\mathbf{n_{air}}$ which is equal to 1. n_2 is the index of refraction we are looking for, our unknown. $\boldsymbol{\theta_1}$ is our incident angle, *angle of incidence [θi]*. $\boldsymbol{\theta_2}$ is our refracted angle, *angle of refraction [θr]*.

1. Using Snell's Law and your measured angles from your diagram, determine the index of refraction of the rectangular glass for your pencil and laser trials.
2. Using Snell's Law and your measured angles from your diagram, determine the index of refraction of the triangular glass for your pencil and laser measurements.
3. Calculate a standard deviation for the rectangular group of trials.
4. Calculate a percent difference between your average pencil index of refraction and average laser index of refraction for each piece of glass.

$$\%Diff = \frac{2\cdot|x_1 - x_2|}{(x_1 + x_2)}\times 100\%$$

5. Once you have determined the indexes of refraction, consult your teacher as to what type of material each plate is, and then look up the actual index of refraction of each in your text book or online.
6. Calculate your percent error while finding the index of refraction for each plate using the formula

$$\%\ error = \frac{actual\ value - measured\ value}{actual\ value}\times 100\ \%$$

7. Redo your index of refraction calculation for the rectangular place and the triangle plate but this time use angles on the side of the plate where the light is coming out. Enter the values in your data table and calculate a percent different from your other calculated values.

QUESTIONS

8. Is there good agreement between your experimental value for the index of refraction of each plate with the actual values? What factors might attribute to any discrepancies?
9. According to your diagrams, are light rays refracted away from or toward the normal as they pass from a less dense medium to a more dense medium (air to glass)?
10. According to your diagrams, are light rays refracted away from or toward the normal as they pass from a more dense medium to a less dense medium (glass back to air)?
11. Compare θ_i to θ_B and θ_B to θ_D. Are the measures of θ_D what you expected? Explain?
12. Use your results to determine the approximate speed of light in each glass plate using what you know about the definition of *index of refraction*.
13. Compare your incoming and outgoing values for index of refraction. Does the side you use to calculate the values affect your values? Should it?

NAME:____ CLASS:_______________

DATA TABLE

ENTER YOUR ANSWERS TO THE ANALYSIS QUESTIONS IN THE SPACES PROVIDED BELOW and TURN IN WITH YOUR LAB REPORT.

RECTANGULAR PLATE

		1	2	3	4	Average **n**	Deviation **σ**
PENCIL	θ_1						
	θ_2						
	n						

		1	2	3	4	Average **n**	Deviation **σ**
LASER	θ_1						
	θ_2						
	n						

% DIFFERENCE BETWEEN PENCIL AND LASER: _______________________

% ERROR BETWEEN ACTUAL AND PENCIL: ____________________

% ERROR BETWEEN ACTUAL AND LASER: ____________________

TRIANGLULAR PLATE

	θ_1	θ_2	n	% ERROR
PENCIL				

	θ_1	θ_2	n	% ERROR
LASER				

% DIFFERENCE BETWEEN PENCIL AND LASER: _______________________

INDEX OF REFRACTION FOR OUTGOING BEAMS

	INDEX OF REFRACTION	% DIFFERENCE		INDEX OF REFRACTION	% DIFFERENCE
RECTANGLE			TRIANGLE		